ASD TECHNICAL REPORT 61-707

MAINTENANCE OF CARDIOVASCULAR ADAPTABILITY DURING PROLONGED WEIGHTLESSNESS

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BIOMEDICAL LABORATORY
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AERONAUTICAL SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND
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NOTICES

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FOREWORD

This report was prepared by the Psychophysiological Stress Section, Biophysics Branch, Biomedical Laboratory, Aerospace Medical Laboratory under Project No. 7222, "Biophysics of Flight," Task No. 7222201, "Psychophysiology of Flight."

ABSTRACT

Special techniques are expected to be necessary during prolonged zero gravity because of the absence of hydrostatic pressure influences to maintain cardiovascular adaptability and provide the orbiting astronaut with optimum tolerance for reentry stresses. A multiple tourniquet approach to intermittently obstruct venous return from the periphery has been devised.

PUBLICATION REVIEW

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INTRODUCTION

Because man in normal gravity is predominately upright, an efficient system of reflex circulatory mechanisms has evolved which compensates for the hydrostatic pressure due to gravity. This hydrostatic pressure influence is a stimulus to the sympathetic control of the circulatory system so that adequate distribution of cardiac output occurs despite positional changes.

In a weightless environment there will be no hydrostatic pressure effects and therefore no demand upon these reflex compensatory changes. Analogous situations occur in bed rest where hydrostatic pressure influences are minimized due to the horizontal position and in water immersion where hydrostatic pressure effects are neutralized because of ambient water pressure.

The loss of cardiovascular adaptability, because of disuse of these compensatory reflexes, is well known from prolonged bed rest and water immersion tests. Following these tests, tilt table studies reveal a deterioration in the capacity of the circulatory system to adjust to the erect posture as well as decreased tolerance to other functional tests; such as, heat chamber, treadmill, and headward acceleration (refs. 1, 2, and 3). It is anticipated that during prolonged zero gravity, similar decrease in the capacity for cardiovascular support will result. In order to provide the orbiting astronaut with optimum tolerance for reentry stresses, maintenance of cardiovascular adaptability must be insured.

The nature of the circulatory impairment appears to be an increased tendency to peripheral pooling of blood with resultant decreased venous return to the heart. Because of prolonged disuse, reflex sympathetic control has become less efficient, contributing to decreased venoconstrictor tone and increased venous pooling. In support of this are the observations that anti-gravity suits or other devices, such as wrapping the lower extremities with Ace bandages, provide complete support of the circulatory system during orthostatic testing. Such devices prevent or minimize peripheral pooling of blood and therefore promote adequate venous return to the heart.

Until recently, suitable "protection" of the astronaut during zero or sub-gravity conditions was generally thought to be obtainable by an adequate program of exercises - such as, muscle tensing, mainpulation of resistive or friction devices, joint resistive suits, etc. However, recent evidence indicates that this concept must be revised considerably. In a recent experiment five subjects were evaluated before and after a 2-week period of bed rest. Three of the subjects exercised daily in bed by doing strenuous exercises of the setup and pushup variety. Although muscle tone was maintained in the three subjects who exercised, they showed the same degree of tilt table and treadmill intolerance at the end of the 2-weeks as the nonexercise subjects, reflecting loss of cardiovascular adaptability. Another recent experiment showed that weighting of the subjects during water immersion so that near normal weight sensations and demands for musculoskeletal support existed throughout the 6-hour tests failed to prevent cardiovascular deterioration. In this latter experiment, normal muscle tone was maintained and the subjects experienced none of the oppressive heaviness usually noted initially upon emersion, yet they showed the same evidence of orthostatic intolerance as existed following their nonexercise immersion tests.

The stimulus for maintenance of cardiovascular adaptability is hydrostatic pressure influences. In the experiments described above despite muscular exercise such influences are absent or minimal and the reflex sympathetic control of circulation deteriorates through disuse. We can logically extend these inferences to the orbital situation and predict that in a weightless environment even with programmed strenous muscular exercise, the compensatory cardiovascular reflexes which depend upon hydrostatic pressure influences will not be maintained.

For a number of years it has been known that an oscillating bed will prevent or significantly modify the loss of circulatory adaptability resulting from prolonged bed rest (ref. 1). Apparently by intermittently tilting the feet down lower than the heart, the resulting hydrostatic pressure head contributes to increased peripheral venous pressure and decreased venous return to the heart in a manner analogous to standing and adequate to stimulate sympathetic reflex control.

Extending this concept further, I have devised for use in the water immersion studies a system of intermittently obstructing venous return from the periphery by the use of multiple limb tourniquets. When inflated they cause increased peripheral venous pressure and decreased venous return to the heart, simulating the hydrostatic pressure effects associated with standing and thereby intermittently "triggering" compensatory cardiovascular reflexes.

The purpose of this article is to present the results of the initial evaluation of this technique for possible application in prolonged zero gravity conditions.

METHODS

A detailed description of the water immersion facility is given in another report (ref. 2). Five healthy young men ranging in age from 21 to 31 years were used as subjects. For all tests, the subjects wore a modified "dry" skin diving suit. A modified partial-pressure helmet permitted balanced respiratory pressures. The subjects had unrestricted activity within the confines of the tank. Following the 6-hour period of immersion with tourniquet protection, the orthostatic tolerance of each subject was determined and compared with that obtained following his previous 6-hour immersion tests done with no protection.

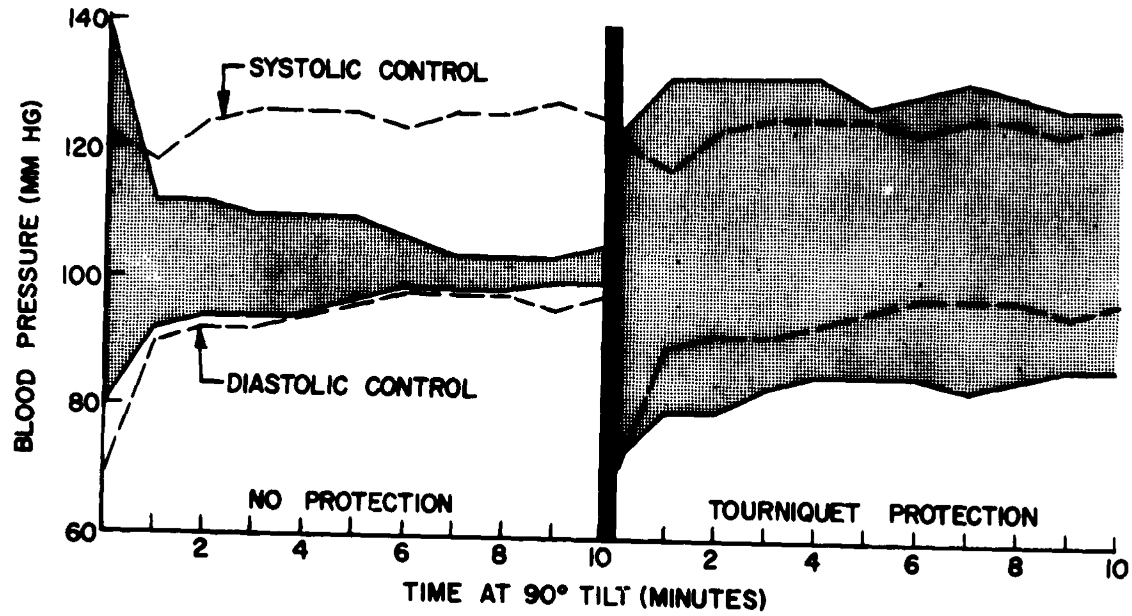
The interconnected tourniquets were applied about the four extremities (figure 1) and connected to an air source and mercury manometer outside the tank. Every 2 minutes the tourniquets were inflated to an effective pressure of 60-mm Hg, held for 1 minute, then released. This was done continuously throughout the 6-hour immersion tests.

Orthostatic tolerance was determined by tilt-table testing, using a 90° tilt for 10 minutes during which time electrocardiograms and blood pressures were obtained at minute intervals. The standard musculatory technique of blood pressure determination was used.

Figure 1. Subject in the Immersion Tank During a 6-Hour Test With Tourniquet Protection

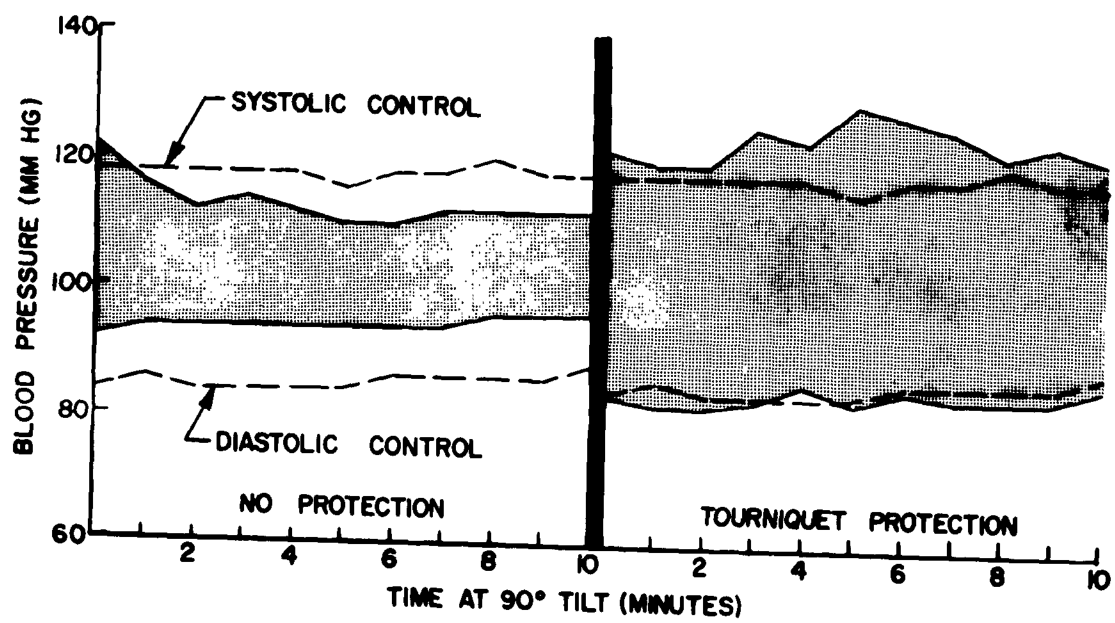
RESULTS

In all subjects, the tourniquet technique maintained normal or better than normal cardiovascular adaptability as measured by tilt table testing. Following previous immersion tests with no protection each subject had a decreased systolic and/or increased diastolic blood pressure contributing to significant narrowing of pulse pressure. One subject (c) routinely had syncope following his previous 6-hour immersion tests and was never able to exceed 5 to 7 minutes of the tilt-table testing. Following immersion, with tourniquet protection, the systolic blood pressure was maintained at or above the control range; the diastolic blood pressure was maintained at or below the control range and wide pulse pressures were maintained throughout in all subjects (figures 2-6).



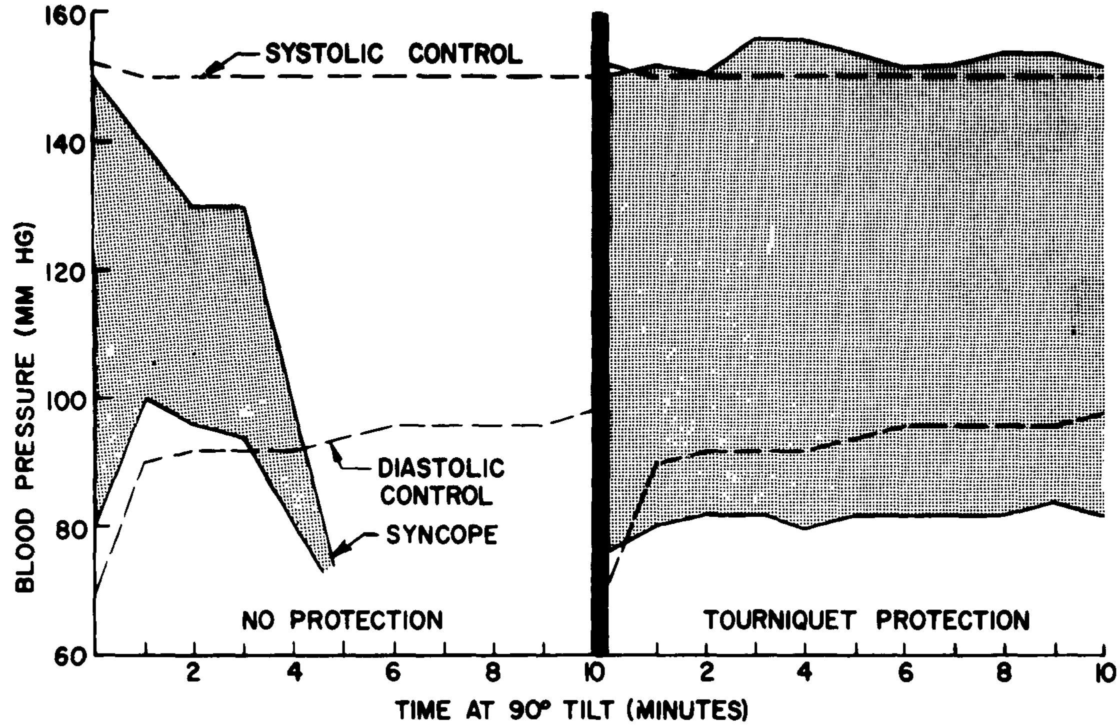
SUBJECT A

Figure 2. Blood Pressure Response to Tilt-Table Testing Demonstrating the Changes From Control Systolic Pressures (Top Dotted Line) and Changes From Control Diastolic Pressures (Bottom Dotted Line) Observed Following Immersion Tests With No Protection (Left) and With Tourniquet Protection (Right).



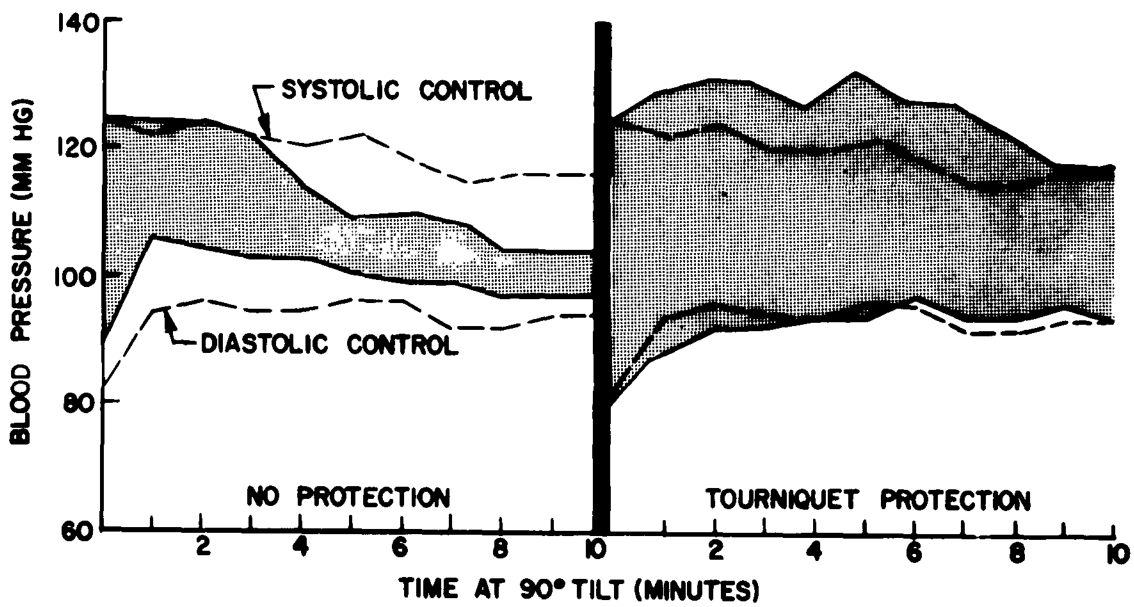
SUBJECT B

Figure 3. Blood Pressure Response to Tilt-Table Testing Demonstrating the Changes From Control Systolic Pressures (Top Dotted Line) and Changes From Control Diastolic Pressures (Bottom Dotted Line) Observed Following Immersion Tests With No Protection (Left) and With Tourniquet Protection (Right).



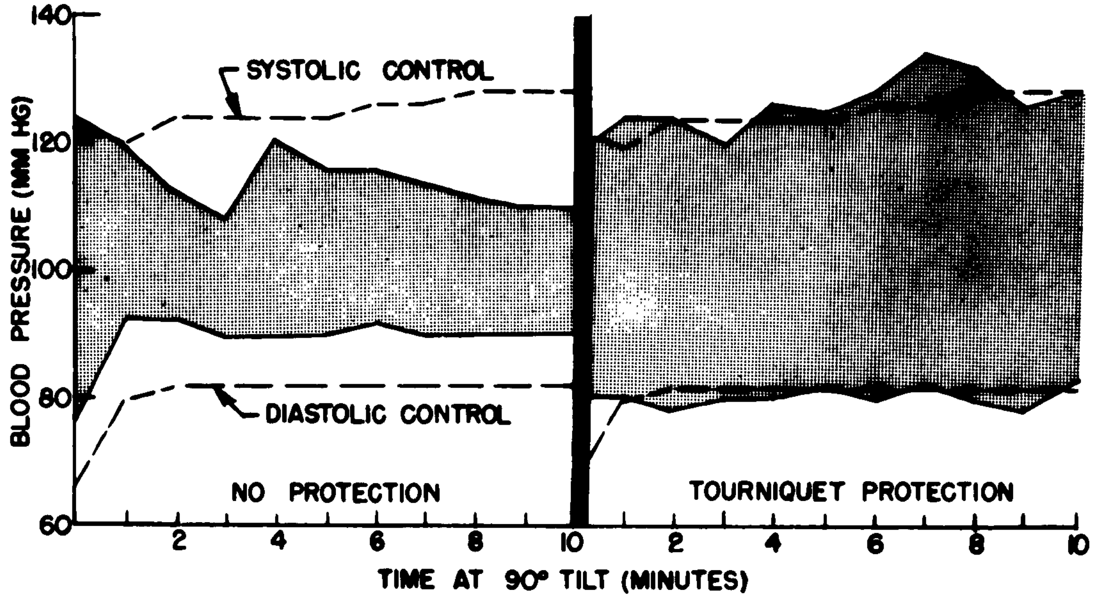
SUBJECT C

Figure 4. Blood Pressure Response to Tilt-Table Testing Demonstrating the Changes From Control Systolic Pressures (Top Dotted Line) and Changes from Control Diastolic Pressures (Bottom Dotted Line) Observed Following Immersion Tests With No Protection (Left) and With Tourniquet Protection (Right).



SUBJECT D

Figure 5. Blood Pressure Response to Tilt-Table Testing Demonstrating the Changes From Control Systolic Pressures (Top Dotted Line) and Changes From Control Diastolic Pressures (Bottom Dotted Line) Observed Following Immersion Tests With No Protection (Left) and With Tourniquet Protection (Right).



SUBJECT E

Figure 6. Blood Pressure Response to Tilt-Table Testing Demonstrating the Changes From Control Systolic Pressures (Top Dotted Line) and Changes From Control Diastolic Pressures (Bottom Dotted Line) Observed Following Immersion Tests With No Protection (Left) and With Tourniquet Protection (Right).

The electrocardiograms revealed that the heart rates of each subject remained in the control range during tilt-table testing and electrocardiographic changes previously observed, such as, increased amplitude of P waves, shifts in the QRS electrical axis, and orthostatic T wave changes were modified considerably.

During orthostatic testing, all subjects had previously become pale with cold, clammy skin and had demonstrated congestion and cyanosis of the dependent extremities. Following tourniquet protection, these changes were not evident during tilting and the appearance of each subject was essentially normal (control).

DISCUSSION

The use of the tourniquet technique as described here is essentially an extension of the oscillating bed principle and probably maintains cardiovascular adaptability by the same general mechanisms. By intermittently obstructing venous return, peripheral venous pressure is increased, blood tends to be pooled in the extremities, and venous return to the heart is decreased. In this manner hydrostatic pressure effects are simulated and the cardiovascular system retains its capacity to adjust adequately during positional changes.

This is the type of protective device which can be integrated readily into any of our currently used pressure garments. The inflation cycle in this study was one minute on, one minute off, throughout the 6-hour test, resulting in venous obstruction about 50 percent of the time. The orthostatic tolerance of all subjects after the immersion test with tourniquet protection was better than control indicating that the inflation profile could be altered either by decreasing effective pressure or by decreasing the total time of obstruction or both.

Much more work is needed to establish the optimum approach. It would certainly be of interest to know if it is necessary to use the device throughout the test period or just in the latter portion. It should be added that this technique neither inconvenienced the subjects nor caused them discomfort. Several subjects slept for short periods during the test.

Regarding additional protective measures one should keep in mind that after prolonged bed rest or water immersion, the anti-g suit is a very effective device to prevent peripheral venous pooling and insure more nearly normal circulatory dynamics. This same benefit will probably be obtained following prolonged weightlessness when such a suit could be effectively utilized during reentry and subsequent gravitational conditions.

One should note that although muscular exercise devices will be necessary for preventing loss of musculoskeletal effectiveness, such devices cannot be expected to maintain cardiovascular adaptability which depends upon hydrostatic pressure influences. Further research is necessary to devise the most efficient approach to protective techniques until such time as adequate artificial gravity is assured.

SUMMARY

During prolonged zero gravity because of the absence of hydrostatic pressure influences, special techniques will be necessary to maintain cardiovascular adaptability and provide the orbiting astronaut with optimum tolerance for reentry stresses. A multiple tourniquet approach to intermittently obstruct venous return from the periphery has been devised, simulating the hydrostatic pressure effects of standing and thereby "triggering" compensatory cardiovascular reflexes. Following 6-hour periods of water immersion with tourniquet protection, the orthostatic tolerance of 5 subjects was determined and compared with that obtained following previous 6-hour immersion tests with no protection. In all subjects the tourniquet technique maintained normal or better than normal cardiovascular adaptability as measured by tilt-table testing.

BIBLIOGRAPHY

1. Whedon, G.D., J.E. Deitrick, and E. Shorr, "Modification of the Effects of Immobilization Upon Metabolic and Physiologic Functions of Normal Man by the Use of an Oscillating Bed," Am. J. Med., Vol 6, p. 684, 1949.

2. Graveline, D.E., Effects of Posture on Cardiovascular Changes Induced by Prolonged Water Immersion, ASD Technical Report 61-651, Aeronautical Systems Division, Wright-Patterson Air Force Base, Ohio, December 1961.

3. Graveline, D.E., and G.W. Barnard, Physiologic Effects of a Hypodynamic Environment - Short Term Studies, WADD TR 61-257, Wright Air Development Division, Wright-Patterson Air Force Base, Ohio, March 1961.

ASD TR 61-707
Aerospace Medical Laboratory, Aeronautical Systems Division, Wright-Patterson Air Force Base, Ohio.
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